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Matthew R. Risser, Mark St. John, David A. Kobus

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14. ABSTRACT
U. S. Army Research Office grant number W911NF-05-C-0094
A real-time closed-loop system for predicting and counteracting lapses of attention
David A. Kobus, Mark St. John, & Matthew R. Risser
Pacific Science & Engineering Group, Inc.

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Report Title

Final Report

ABSTRACT

U. S. Army Research Office grant number W911NF-05-C-0094
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Vigilance tasks, from driving to surveillance to security remain important and frequent tasks for the US Army. Yet the difficulty users have sustaining vigilance is well known. Augmented cognition offers new methods for supporting sustained vigilance via a closed-loop attention management system (CLAM). A CLAM system monitors operators' psychophysiology for signs of inattention and then triggers a countermeasure to rouse operators and help them sustain vigilance and good task performance. There are many requirements for bringing this concept to fruition, including minimal or no contact psychophysiological measures, accurate and precise prediction of attention level and task performance, and effective interface modifications. Over the course of this three year project, we have investigated 1) effective combinations of psychophysiological measures of inattention, 2) effective countermeasures, and 3) a complete closed-loop system for monitoring and sustaining attention and task performance. The project has produced three book chapters and one conference paper. A journal article is under review.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Number of Papers published in peer-reviewed journals: 0.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

St. John, M. & Risser, M. R. (2008). Closed-loop attention management: Using augmented cognition to sustain vigilance. In proceedings of the 26th Army Science Conference. Washington, DC: Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology.

St. John, M., & Risser, M. R. (2007). Mitigating the vigilance decrement: Perceptual versus cognitive interventions. In D.D. Schmorrow, D.M. Nicholson, J.M. Drexler, & L.M. Reeves (Eds.), Foundations of Augmented Cognition, 4th Edition (pp. 81-89). Arlington, VA: Strategic Analysis, Inc.

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Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 3

(d) Manuscripts

St. John, M. & Risser, M. R. (2008). Closed-loop attention management: Using augmented cognition to sustain vigilance. Submitted to Human Factors.

Number of Manuscripts: 1.00

Number of Inventions:

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Mark St. John	0.25	No
Matthew Risser	0.20	No
David Kobus	0.10	No
FTE Equivalent:	**0.55**	
Total Number:	**3**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period:	0.00
The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:.....	0.00
The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:.....	0.00
Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):	0.00
Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:	0.00
The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense	0.00
The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:	0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME	PERCENT_SUPPORTED	
Linda Wu	0.25	No
Linda Suk	0.15	No
Daniel Manes	0.15	No
FTE Equivalent:	**0.55**	
Total Number:	**3**	

Sub Contractors (DD882)

Inventions (DD882)

U. S. Army Research Office grant number W911NF-05-C-0094

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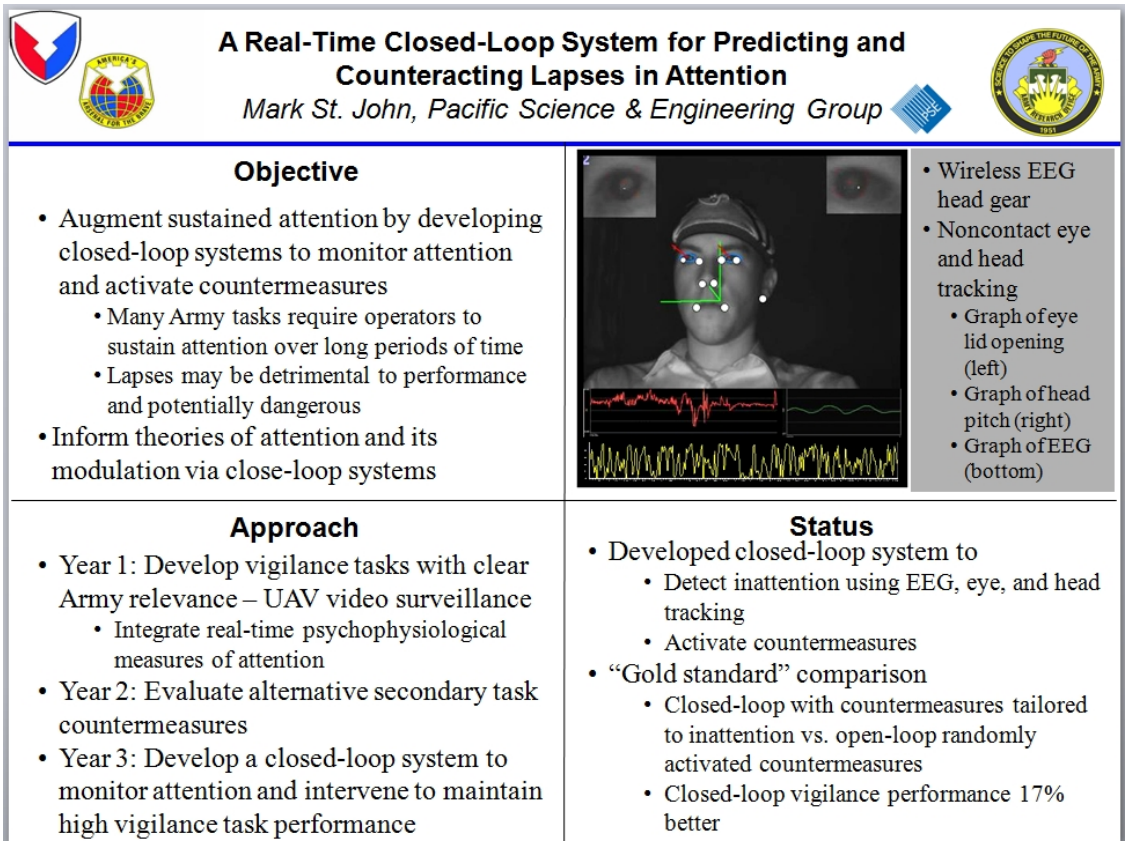
Vigilance tasks, from driving to surveillance to security remain important and frequent tasks for the US Army. Yet the difficulty users have sustaining vigilance is well known. Augmented cognition offers new methods for supporting sustained vigilance via a closed-loop attention management system (CLAM). A CLAM system monitors operators' psychophysiology for signs of inattention and then triggers a countermeasure to rouse operators and help them sustain vigilance and good task performance. There are many requirements for bringing this concept to fruition, including minimal or no contact psychophysiological measures that are minimally invasive or constraining, accurate and precise prediction of attention level and task performance, and effective interface modifications. Over the course of this three year project, we have investigated 1) effective combinations of psychophysiological measures of inattention, 2) effective countermeasures to rouse and re-engage participants once inattention is detected, and 3) a complete closed-loop system for monitoring and sustaining attention and task performance. The project has produced three book chapters and one conference paper. A journal article is under review. Below are abstracts describing the work from each year of the project.



Year 1. In the present study, we report a novel combination of no contact head and eye measures combined with a wireless EEG measure to predict performance on a sustained vigilance task. Each measure was computed for 10 five minute blocks over the course of the experiment. The four most predictive variables were eye opening (vertical distance between eyelids), head pitch variability (amount of nodding), high vigilance (a measure derived from a spectral analysis of the EEG signal), and the sum of the high and low vigilance indices (Berka et al., 2004). Together, the measures predicted 42% of the variance in the miss rate (39% of the variance in A'). No individual variable accounted for more than 13% of the variance. Separate multiple regressions using the same four variables were computed for each participant. The percentage of variance in the miss rate accounted for varied from 32% to 91%. These findings suggest that these minimally invasive measures, used in combination, may be sensitive enough and acceptable enough for use in closed-loop attention management systems in a variety of operational contexts that require optimal continuous performance.

Year 2. The present study presents and tests a novel hybrid model of the underlying mechanisms responsible for the vigilance decrement that combines aspects of both arousal and resource theories. From the new Arousal-Resource model, we derived and evaluated three alternative interventions. The interventions took the form of secondary tasks designed to draw upon resources separate from those required by the primarily visual vigilance task: an auditory alarm "ring tone" that exercised sensory perception only and two auditory cognitive tasks that additionally exercised working memory by requiring participants to mentally reorder strings of 3 or 4 spoken digits. We hypothesized that the cognitive digit task interventions would arouse participants, replenish depleted resources, and re-engage them in the vigilance task. We further hypothesized that the cognitive tasks would prove more effective than the simple alarm because they are more demanding and engaging. Participants performed a standard 45 minute laboratory vigilance task twice, once in a control condition without any intervention and once with one of the three different interventions. In the intervention conditions, participants received the intervention whenever they missed a target. This method for intervention served as a convenient proxy for a closed-loop system in which participants would receive interventions whenever low attention was detected by psychophysiological measures, prior to an actual miss. All three interventions significantly reduced misses by approximately 30%. Participants who showed greater vigilance decrements in the baseline condition showed more improvement from all interventions. Therefore, more vulnerable participants benefited most. The cognitive interventions performed as well as, but no better than, the simple alarm. The cognitive tasks also interfered with target detection performance on occasions when the interventions were active. However, the alarm was rated subjectively as more frustrating and less appropriate than either cognitive intervention. Because the added task demands of the cognitive interventions improved vigilance task performance rather than harming it, the Arousal-Resource model is supported by the results. Secondary tasks may be used to arouse and re-engage participants, and participants appear to prefer these interventions to alarms. However, care should be taken to minimize interference between the primary and secondary tasks.

Year 3. Here, we report an evaluation of a complete closed-loop system composed of a combination of eye, head, and EEG measures and a novel countermeasure composed of a cognitively demanding secondary task. In order to evaluate the CLAM system, the secondary task was triggered either when inattention was detected (CLAM) or at random intervals throughout a 40 minute vigilance task. While participants in both conditions demonstrated a

vigilance decrement, as measured by an increase in misses over the course of the session, the CLAM condition produced 17% fewer misses overall than the random condition. These results indicate successful real-time detection of inattention and an effective countermeasure for rousing participants and sustaining vigilance and task performance. The results inform our understanding of how human vigilance operates and the technology for its detection and manipulation.

Publications

St. John, M. & Risser, M. R. (2008). Closed-loop attention management: Using augmented cognition to sustain vigilance. In proceedings of the *26th Army Science Conference*. Washington, DC: Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology.

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